Summary of Safety and Effectiveness

P970024

❖❖❖❖❖

Angeion Corporation

Sentinel™ Implantable Cardioverter Defibrillator (ICD) System
and
AngeFlex™ Transvenous Defibrillation Lead System

❖❖❖❖❖

Food and Drug Administration
Center for Devices and Radiological Health
Office of Device Evaluation
Division of Cardiovascular and Respiratory Devices

TABLE OF CONTENTS

1.0 General Information

Device Name:	Implantable Cardioverter Defibrillator
Device Trade Name:	Angeion® Sentinel™ Implantable Cardioverter Defibrillator (ICD) System Models 2000/2010/2011/2012 and the Angeion AngeFlex™ Transvenous Defibrillation Lead System Models 4020/4021/4022/4023
Applicant's Name/Address:	Angeion Corporation 7601 Northland Drive Minneapolis, Minnesota 55428-1088
Dates of Panel Recommendation:	None

Premarket Approval Application (PMA) Number: P970024

Date of Good Manufacturing Practice Inspection: February 12, 1997 (sterilizer), June 24, 1997, and April 8, 1998

Date of Notice of Approval to Applicant: August 19, 1998

2.0 Indications for Use

The Angeion® Sentinel™ Implantable Cardioverter Defibrillator (ICD) System Models 2000/2010/2011/2012 and the Angeion AngeFlex™ Transvenous Defibrillation Lead System Models 4020/4021/4022/4023 (hereinafter called the Sentinel ICD System) is indicated for use in patients who are at risk of sudden death due to ventricular arrhythmias and have experienced one of the following situations:

- Survival of at least one episode of cardiac arrest (manifested by loss of consciousness) due to a ventricular tachyarrhythmia
- Recurrent, poorly tolerated, sustained ventricular tachyarrhythmia

NOTE: The clinical outcome for hemodynamically stable VT patients is not fully known. Safety and effectiveness studies have not been conducted.

3.0 Contraindications

The Sentinel ICD System is contraindicated for patients who have:

- Ventricular tachyarrhythmias that have demonstrated a reversible cause such as digitalis intoxication, electrolyte imbalance, drug induced hypoxia, sepsis, or a transient cause attributable to such factors as acute myocardial infarction, electrocution, or drowning.
- A unipolar pacemaker, or a pacemaker that defaults to unipolar mode.

The ICD may also be contraindicated for patients who have:

- Uncontrolled supraventricular tachyarrhythmia (SVT) and excessive ventricular rates despite conventional drug therapy. Depending on the programming detection criteria, SVT may cause therapy delivery.
- Ventricular tachyarrhythmias that require frequent shocks. Frequent shocks may cause intolerable patient discomfort and the ICD batteries to deplete more rapidly than is acceptable.

The Programming Head, Test Electrode, and Patient Cable are contraindicated for use with any device other than the Sentinel ICD or Defibrillation Test System (DTS), or with any external stimulators that do not meet electrical specifications for the non-invasive programmed stimulation (NIPS) interface.

Lead use is contraindicated for those patients with tricuspid valvular disease or any type of tricuspid replacement heart valve (mechanical or tissue).

4.0 Warnings and Precautions

See attached labeling.

5.0 Device Description

The Sentinel ICD System and the AngeFlex Defibrillation Lead System consist of the following: **Sentinal ICD System** - Sentinel ICD Models 2000, 2010, 2011 and 2012; System Programmer Models 3002 and 3007; External Printer Model 3008; Smart Wand™ Programming Head Model 3003; Defibrillation Test System (DTS) Models 7001 and 7002; Test Electrode Model 5007; and, Patient Cable Models 5006 and 5020; **AngeFlex Transvenous Defibrillation Lead System** - AngeFlex Transvenous Defibrillation Lead Models 4020, 4021, 4022 and 4023; any commercially available active fixation bipolar pace/sense leads; Model 5009 Defibrillation Lead Adapter; and accessories - Models 5015 defibrillator magnet, 5025 defibrillator torque wrench/setscrews, 5026 mineral oil, 5027 port plugs, 5029 medical adhesive, 5030 vein picks/lead caps, 5032 AngeFlex suture sleeves, 5033 suture sleeves (10 Fr), 5034 stylet (69 cm), and 5035 stylet (58 cm).

5.1 The Sentinel ICDs

The Sentinel ICDs are battery-operated devices capable of detecting and treating episodes of bradycardia and tachycardia. The Sentinel ICDs are fully programmable, two-zone, tiered therapy devices that incorporate antitachycardia pacing (ATP), cardioversion, and defibrillation tachyarrhythmia therapies and bradycardia pacing support (VVI mode). In addition, the can of the Sentinal ICD may be programmed to serve as a Hot Can™ electrode. The Sentinel ICD circuitry is contained in a hermetically sealed titanium can and consists of discrete electrical components, hybrid circuit assemblies, the ASEC™ dual battery system, Small Cap™ high voltage capacitors, and a telemetry antenna. The header is made of polyurethane and provides electrical connection to the pacing and defibrillation leads. The headers on the Models 2000/2010 Sentinal ICDs are identical and accept two DF-1 compatible lead ends for high voltage defibrillation and two IS-1 lead compatible ends for pacing and sensing. The header on the Model 2011 accepts one DF-1 and one IS-1 lead connector. The IS-1 and DF-1 are international

standards for lead-to-pulse generator connection. The Model 2012 Sentinal ICD accepts two 6.1 mm defibrillation leads and two 4.75 mm pace/sense lead connectors. The Sentinel ICDs range in weight from approximately 108 to 110 grams with a volume of 58 to 61 cubic centimeters.

5.1.1 Sensing and Detection

There are two tachyarrhythmia detection and therapy zones for the Sentinel ICD: Low Zone and High Zone. (Please refer to Table 1 for the programmable parameters of the Low Zone and to Table 2 for the programmable parameters of the High Zone.) The Low Zone detects and treats lower rate tachyarrhythmias, while the High Zone detects and treats higher rate tachyarrhythmias. The detection boundaries for both of these zones are based upon pre-programmed criteria determined by the user. Once the Sentinal ICD has detected an arrhythmia, it can deliver therapy from that zone of detection (the Sentinal ICD can also be programmed with Tachy Therapy "OFF", or be programmed to monitor, detect, and record arrhythmias without delivering therapy).

Detection of a tachyarrhythmia is an algorithmic process which monitors the combination of tachyarrhythmia rate presenting itself in a detection zone, and the continuation of the tachyarrhythmia (duration) in the zone. An appropriate response is then processed. Detection can occur in only one zone, and is the means by which a specific programmed therapy will be selected.

Table 1: *Low Zone Detection*

Parameter	Description	Programmability
Low Zone Rate	If the heart rate meets or exceeds this setting, the ICD recognizes a Low Zone arrhythmia	100 to 245 bpm in steps of 5
Low Zone Duration	Determines how many cardiac cycles are required to occur in the Low Zone before the ICD can prepare and deliver Low Zone therapy	4 to 100 cycles in steps of 2
Low Zone Counter Reset (Models 2010, 2011 and 2012 only)	When this Low Zone parameter is met, the Low Zone and Boundary Zone counts are reset to 0	1 or 2 consecutive cycles
Sudden Onset	Provides additional assessment criteria for tachycardias occurring in the Low Zone	On or Off
Sustained High Rate (minutes)	Determines the length of time a gradual inception arrhythmia is allowed to continue by providing a programmable time limit to the Sudden Onset's therapy inhibition	• Infinite • 0.5 to 29 minutes in steps of 0.5 min. • 30 to 60 minutes in steps of 2 min. (30 minutes max.for Model 2000)
Boundary Zone	Extends 10 bpm above and below the programmed High Zone rate	Non-programmable

Table 2: *High Zone Detection*

Parameter	Description	Programmability
High Zone Rate	If the heart rate meets or exceeds this setting, the ICD recognizes a High Zone arrhythmia	105 to 250 bpm in steps of 5 bpm
High Zone Duration	If the number of High Zone cardiac cycles meets this parameter value, the ICD prepares High Zone Therapy (depending on Boundary Zone count).	4 to 30 cycles in steps of 2 cycles
High Zone Counter Reset (Models 2010, 2011 and 2012 only)	When the High Zone parameter is met, the High Zone and Boundary Zone counts are reset to 0	1 or 2 consecutive cycles
Boundary Zone	Extends 10 bpm above and below the programmed High Zone rate	Non-programmable

In addition, High Zone detection can occur when 12 of the previous 16 R-R intervals reflect a rate at or above the High Zone rate.

Once an arrhythmia has been detected in either the Low Zone or High Zone, the Sentinal ICD can prepare and deliver an appropriate therapy. The Sentinal ICD is capable of delivering a sequence of therapies for both zones. If an arrhythmia is redetected following delivery of the first therapy (Therapy 1), a second therapy (Therapy 2) may be prepared and delivered originating from the zone of re-detection (a therapy will not be delivered from the Low Zone if a High Zone therapy has already been delivered in the episode). The Sentinal ICD will deliver up to five therapies to treat a single arrhythmia episode. If the arrhythmia has not been terminated after five therapies have been delivered (from either the Low or High Zones), the Sentinal ICD will cease to deliver therapy. The Sentinal ICD resumes normal detection and therapy if the cardiac rate drops below the Low Zone rate for more than 20 consecutive cycles.

5.1.2 Therapy

Therapy for the Sentinel ICD is organized into Low Zone Therapy and High Zone Therapy. In addition, induction is available through use of Non-Invasive Programmed Stimulation (NIPS); and Coupled Shock Induction. Low and High Zone Therapy parameters are described in Tables 3 and 4.

Table 3: ***Low Zone Therapy***

Therapy	Description	Programmability	
THERAPY 1: *Anti-Tachy Pacing (ATP)*	Therapy consisting of one or more bursts of a sequence of pacing pulses. ATP employs adaptive, interval decremental, overdrive pacing with pulse count increment.	**Parameter** • Initial # of Pulses • Coupling Interval (%) • Ramp Decrement • Number of Bursts • Coupling Interval Decrement (Models 2010, 2011 and 2012 only)	**Option(s)** • 1 to 15, in steps of 1 • 60 to 95, in steps of 5 • 0 to 40 ms in steps of 2 ms • 1 to 10 in steps of 1 • 0 to 40 ms in steps of 2
Cardioversion	Termination of a tachyarrhythmia by a shock delivered in a 2 ms monophasic pulse simultaneous with a sensed cardiac event (if no cardiac activity is detected by the end of one second, the ICD will deliver the shock asynchronously at that time).	0.27, 0.6, 1.0, 1.6, 2.4, 3.3, 4.3 (joules)	
Defibrillation Shock	Termination of a tachyarrhythmia by a monophasic or biphasic shock (depending on the selected waveform parameter) delivered simultaneously with a sensed cardiac event (if no cardiac event is detected by the end of one second, the ICD delivers the shock asynchronously at that time).	0.1, 0.9, 2.9, 4.2, 5.8, 7.6, 9.6, 11.8, 14.3, 17.1, 20.0, 23.2, 26.7 (joules)	
THERAPY 2: *Cardioversion*	See description above.	Same parameters as above.	
Defibrillation Shock	See description above.	Same parameters as above.	
THERAPIES 3-5: *Defibrillation Shock*	See description above.	26.7 joules, non-programmable	

Table 4: ***High Zone Therapy***

Therapy	Description	Programmability
THERAPY 1:		

Defibrillation Shock	Termination of a tachyarrhythmia by a monophasic or biphasic shock (depending on the selected waveform parameter) delivered simultaneous with a sensed cardiac event (if no cardiac event is detected by the end of one second, the ICD delivers the shock asynchronously at that time).	0.1, 0.9, 2.9, 4.2, 5.8, 7.6, 9.6, 11.8, 14.3, 17.1, 20.0, 23.2, 26.7 (joules)
THERAPIES 2-5: *Defibrillation Shock*	See description above.	26.7 joules, non-programmable

Prior to delivery of a cardioversion or defibrillation shock, the Sentinal ICD capacitors are charged based upon the therapy to be delivered. The charging period depends on the therapy energy level and battery status. It varies from less than one second to approximately nine seconds at Beginning-of-Life (BOL), 24 seconds at Elective-Replacement-Indicator (ERI), and 32 seconds at End-of-Life (EOL). Periodically, the Sentinal ICD capacitors are automatically charged to maintain proper device operation. This ensures optimum function of the capacitors and occurs according to an automatic schedule. In addition, the Sentinel ICD is capable of delivering the following types of therapies:

Non-Invasive Programmed Stimulation (NIPS)

NIPS is a method of inducing tachyarrhythmias through the leads system using an external stimulator (pacing) device (i.e. EP stimulator or external pulse generator) to command Sentinal ICD pulses. These external stimulators are connected directly to the cable of the Smart Wand programming head, delivering NIPS to the patient. The external stimulator sends a pulse to the Smart Wand which then sends a telemetry command to the Sentinal ICD. This causes the Sentinal ICD to provide a 2 ms pacing pulse (successive pulses can follow at intervals as short as 20 ms).

Coupled Shock Induction (Models 2010, 2011 and 2012 only)

Coupled shock allows the physician the option of having the Sentinal ICD deliver a programmed, low-energy shock that is delayed from a sensed R wave by a programmable time delay coupling interval to coincide with a T wave. The delivery of a coupled shock is commanded via telemetry through the system programmer and Smart Wand programming head. Defibrillation energy values for coupled shock induction can be programmed to: 0.1, 0.4, 0.9, 1.9, 2.9 and 4.2 (joules). Time delays can be selected to 0 ms, or 50 to 500 ms in steps of 10 ms. Coupled shock is used to intentionally induce fibrillation for patient evaluation.

Defibrillation Waveforms

All defibrillation shocks delivered by the Sentinal ICD are in a selected waveform. The physician is able to select either a Monophasic or Biphasic defibrillation pulse:

- *Monophasic* - An exponential waveform truncated 1.6 ms after 44% tilt is reached.
- *Biphasic* - A two-phase pulse (the monophasic pulse and a pulse of the opposite polarity) with a 0.5 ms delay between phases.

Monophasic and Biphasic defibrillation energy values are a function of capacitor voltage and stored energy value.

5.1.3 Diagnostics

The Sentinel ICD is capable of storing information, including diagnostic information, in memory and retrieving it for analysis by the user. The types of stored diagnostic information are as follows:

Table 5: *Stored Information*

Element	Description
Event History	The ICD stores events that comprise a tachyarrhythmia episode. The ICD stores up to 128 tachyarrhythmia events (50 events for Model 2000) in the ICD's memory. Event History can be reviewed and printed through the programmer.
EGM and Marker Data	The ICD can be programmed to record segments of EGM and Marker data associated with tachyarrhythmia episodes. This function can be programmed to three settings: Off; On with ATP; On without ATP. Stored Electrograms are available only with ICD Models 2010, 2011 and 2012 (not available with Model 2000).
Counters (Patient History)	The ICD stores information on the following events: • *Non-Sustained Tachy Episodes* • *ATP Attempts* • *ATP Successes* • *Shock Attempts* • *Shock Successes* • *Non-Committed Shock Aborts* • *Programmer Therapy Shocks* • *Programmer Induction Shocks (2010, 2011, 2012 only)* • *Capacitor Reform Charges* The ICD stores Resettable Counters (which can be reset using the programmer) and Lifetime Counters (permanently stored in the ICD)
Non-Sustained Activity	When a tachyarrhythmia begins but is not sustained for a sufficient number of intervals to be considered an episode, it is recorded by the ICD as a non-sustained episode.
Shock Lead Impedance	Shock lead impedance is the effective resistance of the patient lead system to the defibrillation shock current. The programmer will display the current shock lead impedance (from the Data Options Menu) to a maximum of 243 ohms.
ICD Battery Status	The ICD stores information on the battery status, including battery voltage and battery level (these are displayed by the programmer). Under battery level, the programmer will indicate if the voltage is "OK," if Elective Replacement Indicator (ERI) is reached, or if End-of-Life (EOL) is reached.
ICD Status	The ICD stores a record of status messages in memory with information about its operation, stamped with system date and time. The ICD can save up to 14 status messages.
Patient Information	The ICD stores six blocks of patient information, including two designated for patient name and identification number. The remaining four may be used to record any information the user may require.

5.2 Sentinel Programming Systems

The Sentinel ICD System consists of the Models 3002 and 3007 Programmers with an off-the-shelf Model 3008 External Printer and the Model 3003 Smart Wand that interrogate and program the Sentinal ICD and DTS devices using radio frequency telemetry. The Programmers are IBM-compatible, off-the-shelf laptop computers that are loaded at Angeion, with Angeion custom designed software for communicating with the Sentinal ICD and the DTS devices. The Model 3002 Programmer uses an Intel 486SX 33MHz processor with standard 4MB of RAM and 120MB or 200MB hard drive. The Model 3007 uses an Intel 100 MHZ Pentium processor with 8 MB of RAM (expandable to 40 MB) and 810 MB hard drive.

5.3 Defibrillation Test Systems

The Models 7001 and 7002 DTS consist of identical D-cell (8) battery powered hardware boxes that are designed to facilitate implant testing of the Sentinel ICD. The DTS provides connections between the patient, Model 5007 Test (can) Electrode and leads using the Models 5006 and 5020 Patient Cables. The Models 7001 and 7002 DTS differ only by software, where only the Model

7002 employs coupled shock induction capability. The DTS consists of a plastic box housing and two printed circuit boards (indicator board and the main board), and weighs approximately eight pounds with batteries installed. The DTS also has a rescue button that, if needed, is capable of delivering a 40 joule rescue shock.

5.4 Lead Systems

The AngeFlex Transvenous Defibrillation Lead is available in four models 4020/4021/4022/4023. The four models are constructed using identical materials and processes, and differ only in overall length and electrode spacing. The two lengths of electrode spacing (13 and 17 cm) are measured from the distal end of the lead to the distal end of the Superior Vena Cava (SVC) electrode. This is designed to offer the physician optional lengths based upon patient anatomy. All lead models have both a Right Ventricle (RV) and SVC shocking electrode and are designed to connect to the Sentinel ICD using DF-1 connectors. In addition, the Model 5009 Defibrillation Lead Adapter can be used to connect a 6.1mm lead to the DF-1 connector of the Sentinel ICD.

6.0 Alternative Practices and Procedures

Alternative therapies for the treatment of life threatening ventricular arrhythmias, as deemed appropriate by the physician based upon electrophysiology testing and other diagnostic evaluation include the use of antiarrhythmic drugs, ablation and cardiac surgery, and the use of devices including commercially available pacemakers and ICDs.

7.0 Marketing History

The Sentinel ICD System has been commercially distributed in the European Union as a CE-Marked product since April 17, 1996. Approximately 70 Sentinal ICD Systems have been distributed throughout Germany, United Kingdom, and Italy. The Sentinal ICD System has not been withdrawn from marketing for any reason relating to the safety and effectiveness of the device.

8.0 Adverse Events

The Sentinel ICD System clinical investigation involved 143 devices implanted in 138 patients with 1130 cumulative implant months (mean implant duration was 8 months). The Sentinel ICD System was evaluated using the AngeFlex Transvenous Defibrillation Lead System Models 4020/4021/4022/4023, the AngePass Defibrillation Lead System 4040/4080 Series, the Endocure 1500 Series Defibrillation Lead System, or a market approved chronic defibrillation lead system. The 66 observations and 8 complications presented in the tables that follow reflect the reported clinical events and experience with the Sentinel ICD System (see Tables 6 and 7). There were eight patient deaths reported during the clinical investigation; these were not attributed to the function or use of the Sentinel ICD System. Rates of occurrence of observations and complications reported in the Sentinel ICD System study were similar to the rates of adverse events experienced by other manufacturers with similar products.

8.1 Clinical Observations

Table 6: ***Summary of Clinical Observations***

All patients treated: Sentinel ICD series (N = 138 patients), AngeFlex Defibrillation Lead Systems (N = 70 patients), Endocure lead system (N = 56), AngePass lead system (N = 4) and chronic lead systems (N = 8). Sixty-six observations occurred in a total of 40 patients, some of whom had multiple events. (Total Device Months = 1130)

Event	Number of Events	Number of Patients	Incidence Rate: # Events / # Device Months
System Related (27)			
ICD Reprogramming/Medication Change	10	10	0.009%
ICD Reprogramming	9	9	0.008%
Appropriate Defib Shock Patient Follow-Up	1	1	0.001%
DTS Extended Induction Time	1	1	0.001%
High Pacing Thresholds	3	3	0.003%
Endocure/AngeFlex Stylet Incompatibility	1	1	0.001%
ICD header/lead incompatibility	1	1	0.001%
Inappropriate Shock Therapy	1	1	0.001%
Other Observations (39)			
Cardiovascular Medication Change	11	10	0.010%
Witnessed Phantom Shock	2	1	0.002%
Abdominal Discomfort	1	1	0.001%
GI Pain, Deemed to be Severe Constipation	1	1	0.001%
CHF	5	5	0.004%
Palpitations	1	1	0.001%
Mitral Valve Replaced	1	1	0.001%
GI Bleed	2	2	0.002%
CVA	1	1	0.001%
Thrombophlebitis	1	1	0.001%
Pneumonia	2	2	0.002%
Cardioversion (external) for AF	1	1	0.001%
Sepsis	1	1	0.001%
Dysphagia	1	1	0.001%
Incision Pain	1	1	0.001%
Ablation	3	3	0.003%
Pacemaker Implant	3	3	0.003%
Prostate Cancer/Device turned off	1	1	0.001%
Total	**66**	**40**	**0.058%**

8.2 *Clinical Complications*

Table 7: *Summary of Clinical Complications*

All patients treated: Sentinel ICD series (N = 138 patients), AngeFlex Defibrillation Lead Systems (N = 70 patients), Endocure lead system (N = 56), AngePass lead system (N = 4), and chronic lead systems (N = 8). Eight complications were reported in 7 patients. (Total Device Months = 1130). Complications, defined as reported events which require invasive resolution, are presented below.

Complications	Status	Number of Events (E), N = 8	Incidence Rate (% E/Device Months)
ICD repositioning due to discomfort. (Submuscular to Subcutaneous)	Resolved	1	0.001
Lead/ICD reconnection after pocket closure due to inappropriate sensing.	Resolved	1	0.001
Lead repositioned due to high pacing threshold.	Resolved	1	0.001
ICD explanted due to inappropriate sensing. ICD replaced.	Resolved	1	0.001
Lead/ICD explanted due to inappropriate sensing. ICD/ Pace/Sense lead replaced	Resolved	1	0.001
ICD/Adapters explanted due to noise from damaged epicardial leads. ICD replaced.	Resolved	1	0.001
ICD explanted due to inappropriate sensing. ICD replaced.	Resolved	1	0.001
ICD explanted due to low battery voltage caused by 10 µF ceramic capacitor leakage. ICD replaced.	Resolved	1	0.001

8.3 *Potential Adverse Events*

Physical patient complications related to the use of an ICD include, but are not limited to, the following:

- Acceleration of arrhythmias
- Air embolism
- Bleeding
- Body rejection phenomenon
- Chronic nerve damage
- Erosion
- Excessive fibrotic tissue growth
- Extrusion
- Fluid accumulation
- Formation of hematomas or cysts
- ICD electrical and mechanical complications
- Inappropriate shocks
- Infection
- Keloid formation
- Lead abrasion
- Lead discontinuity
- Lead migration/dislodgment
- Myocardial damage
- Pneumothorax
- Shunting current or insulating myocardium during defibrillation with internal or external paddles
- Potential mortality due to inability to defibrillate or pace
- Thromboemboli
- Venous occlusion
- Venous or cardiac perforation

8.4 Potential Psychological Events

Psychological patient complications related to the use of an ICD system include, but are not limited to:

- Dependency
- Depression
- Fear of premature battery depletion
- Fear of losing shocking therapy capability
- Fear of shocking while conscious
- Fear of device failure
- Fear of another person being injured, during physical contact, if the device discharges
- Imagined shocking

9.0 Summary of Pre-Clinical Studies

The qualification of the Sentinel ICD System included: bench testing of components, devices, accessories; system level studies (including hardware and software testing); biocompatibility studies; and, animal studies. Table 8 is a summary of these tests; "Pass" denotes that the test results met the company's device specifications.

Table 8. ***Summary of testing performed for sub-assembly and assembly levels, biocompatibility tests, and animal studies***

Test Performed	Number of Samples	Test Result
ICD Sub-Assembly / Assembly Level:		
H-Bridge Hybrid Qualification Report	28	Pass
Power Source, Li SVO Battery Assembly	13	Pass
Transformer, Toroid Qualification Report	15	Pass
Implantable Defibrillator Circuit Board #1 Qualification Report	5	Pass
Implantable Defibrillator Circuit Board #2 Qualification Report	5	Pass
Implantable Defibrillator Circuit Board #3 Qualification Report	5	Pass
Implantable Defibrillator Flex Circuit Board Qualification Report	5	Pass
Flex-Stack Qualification Report	15	Pass
Implantable Defibrillator Antenna Qualification Report	3	Pass
Implantable Defibrillator Circuit Board #3 Qualification Report, Model 2010	5	Pass
Test Report, Four-Port Header, Model 2010 Insertion and Withdrawal Test Item	10	Pass
Test Report Leads, Model 402X Connector Electrical Isolation	7	Pass
Test Report, Two-Port Header, Model 2011 Set-Screw Seal Integrity Test Item	10	Pass
Test Report, Header Connection Fixation Integrity Test Item (Model 2000)	6	Pass
Test Report, Two-Port Header, Model 2011 Insertion and Withdrawal Test Item	10	Pass
Test Report, 6.1 Header, Model 2012 Insertion and Withdrawal Test Item	5	Pass
Test Report, 6.1 Header, Model 2012 Connector Electrical Isolation Test Item	10	Pass
Test Report, 6.1 Header, Model 2012 Fixation Integrity Test Item	6	Pass
Test Summary Report for Model 2000 ICD: Software, Hardware, Environmental	N/A	Pass
Test Summary Report, Functional Device Test, ICD	N/A	Pass
Test Summary Report, System, Model 2000 ICD, Software Integration	N/A	Pass
Defibrillator/Pacemakers, Susceptibility Report	2	Pass
Qualification Test Report, Distribution Simulation Test, ICD Model 2010	3	Pass
Test Summary Report for Model 2010 Family ICD: Software, Hardware, Environmental	N/A	Pass
Test Summary Report, Functional Device Test for Model 2010 Series ICD	N/A	Pass
Software Integration Test Summary Model 2010 ICD	N/A	Pass
Leads and Accessory Reports:		
Test Report Leads, Model 40XX Stylet, Connector and Introducer Insertion/Withdrawal Force; and Set Screw Deformation	7 leads 8 headers	Pass

Test Performed	Number of Samples	Test Result
Test Report Leads, Model 40XX Terminations, Bonds, and Tines	Various samples (19, 16, 15) depending on bond location	Pass
Test Report, AngeFlex Lead with DFT Outer Coil Flex Fatigue Test Item	16	Pass
Test Report Leads, Model 402X Thermal Cycling	10	Pass
Test Report Leads, Model 402X Air Pressure	7	Pass
Test Report Leads, Model 402X Connector Electrical Isolation	9	Pass
Test Report Leads, Model 4020 Series Clavicle First Rib	10	Pass
Test Report Leads, Model 4020 Series Anchoring Sleeve	15	Pass
Test Report Leads, Model 402X Burst and Peel	6	Pass
Test Reports Leads, Model 40XX Shipping Test	7	Pass
Test Report Leads, 6.1 to DF-1 Adapter Workmanship Test Item	20	Pass
Test Report Leads, 6.1 to DF-1 Adapter Connector Introducer Insertion/Withdrawal, Set Screw Deformation Test Item	5	Pass
Test Report Leads, 6.1 to DF-1 Adapter Conductor Terminations and Joint Bonds Test Item	Various samples (15, 13, 10) depending on bond location	Pass
Test Report Leads, 6.1 to DF-1 Adapter Thermal Cycling Test Item	32	Pass
Test Report Leads, 6.1 to DF-1 Adapter Lead Durability and Insulation Integrity Test Item	6	Pass
Test Report Leads, 6.1 to DF-1 Adapter Connector Electrical Isolation Test Item	6	Pass
Test Report Leads, 5.1 to DF-1 Adapter Set Screw Seal Integrity Test Item	5	Pass
Test Report Lead, Model 40XX Flex Testing (as referenced by AngeFlex Test Report)	16	Pass
Test Report Leads, 6.1 to DF-1 Adapter Package Shipping Test Item	5	Pass
Test report Leads, 6.1 to DF-1 Adapter Pressure Burst and Peel Strength Test Item	6	Pass
Externals and Accessories Reports:		
Test Summary Report for Model 2000 Programmer System: Software, Hardware, Environmental	Various samples, depending on the tests	Pass
Test Summary Report for Model 2010/2011/2012 Programmer System: Software, Hardware, Environmental	Various samples, depending on the tests	Pass
Qualification Test Report, Distribution Simulation Test, System Programmer Model 3007	3	Pass
Test Summary Report, SYP IDF Application Integration Test	1 System	Pass
Test Summary Report, SYP IDF Functional Test	1 System	Pass
Test Summary Report, Model 2000 IDF	1 System	Pass
Test Summary Report, SYP DTS Application Integration Test	1 System	Pass
Test Summary Report, SYP/DTS Functional Test	1 System	Pass
Test Summary Report, Model 7001 DTS	DTS, Smart Wand, Programmer Software	Pass
Test Summary Report, SYP, ICD Model 2010-Series Application Software Integration Test	ICD/Programmer System	Pass
Test Summary Report, SYP, Functional Device Test for Model 2010-Series ICD Application	ICD/Programmer System	Pass
Test Summary Report, Model 2010 ICD	2010/3003/3002 Software	Pass
Test Summary Report for Model 2010 Phase II (400229-001 & 700033-001) plus Addendum to Test Summary Report for Model 2010 Phase II	2010/DTS/Smart Wand/Programmer Software	Pass
Qualification Test Report, Distribution Simulation, Test Printer Model 3008	3	Pass
Test Summary Report for the DTS 7001	N/A	Pass
Test Summary Report for the DTS 7002	N/A	Pass
Test Summary Report, DTS Functional Device	N/A	Pass
Qualification Test Report, DTS, Model 7001	5	Pass
Qualification Test Report, Final Device, DTS, Model 7002	2	Pass
Smart Wand Main Board Assembly Qualification Report	5	Pass
Smart Wand RF Board Assembly Qualification Report	5	Pass
Test Summary Report for Model 3003 Smart Wand: Hardware, Software, Environmental	1 each	Pass
Qualification Test Report, SWD, Model 3003	2	Pass
Test Report, Test Can Electrode Summary: Thermal Cycling; Burst and Peel Strength (Packaging); Workmanship; Terminations, Bonds and Welds; DC Resistance and Conductor Integrity; Insulation Integrity	5	Pass

Test Performed	Number of Samples	Test Result
Animal Study Reports:		
Pre-Clinical Investigation of the Sentinel ICD and AngeFlex Defibrillation Lead Systems, Animal Study Report	21 canines	System performed as intended (per Angeion's requirements) in a clinical laboratory environment
Pre-Clinical Evaluation of the Model 2010 Software Application, Auto Recognition, and Model 7002 Software Application (Phase II Software) with the Sentinel Devices, Programming System, and DTS, Animal Study Report	1 canine	System performed as intended (per Angeion's requirements) in a clinical laboratory environment
Biocompatibility Reports:		
Test Report, Sentinel Implantable Cardioverter Defibrillator, Model 2000 Biocompatibility Testing	Various samples sizes depending on each test	Pass
Special Evaluation: Pellethane ICD Header, Autoclave vs. EtO Sterilized Material Comparison	2	Pass
Test Report, Two-Port ICD Header, Model 2011 Biocompatibility Testing	42	Pass
Test Report, AngeFlex Transvenous Defibrillation Leads, Model 4020 Series Biocompatibility Testing	Various sample sizes depending on each test	Pass
Test Report, AngeFlex Lead Supplementary Biocompatibility Testing	17	Pass

9.1 Sentinel ICD Component Bench Tests

The electronic components of the Sentinel ICD were subjected to qualification of the individual component, subassembly and device level depending on the particular component. The qualification consisted of electrical, mechanical, dimensional, and visual requirements, depending on the component or subassembly. The electronic circuitry of the ICDs was subjected to qualification testing including electrical, temperature cycling, visual, and vacuum bake with visual exams. The batteries for the Sentinel ICDs were subjected to environmental stresses followed by visual exam, dimensional analysis, radiographic analysis, electrical and hermeticity testing. Additionally, the battery dissipation characteristics over the life of the battery were determined. Based on the longevity calculations, the estimated longevity of the ICD is between 5 and 9.3 years. The calculation for 5 years is based on 100% pacing and 12 shocks per year, and the calculation for 9.3 years is based on 0% pacing and 4 shocks per year. The high voltage shocking capacitors of the Sentinel ICD were qualified to meet the following requirements: external visual and mechanical, internal visual, DC current leakage, capacitance, mechanical shock and vibration, temperature cycling, charge/discharge testing, and life testing.

9.2 Sentinel ICD/System Bench Tests

- Mechanical/environmental testing of the Sentinel ICD devices consisted of exposure to diagnostic ultrasound, vibration, drop, and temperature cycling testing. Tests were also performed to verify visual, adhesion, and electrical requirements for the associated header connectors of the ICDs.
- Electrically, Sentinal ICDs were tested for performance of programmed parameters and non-programmable settings. Pulse rate, pulse width and amplitudes were also verified as part of the testing.
- The Sentinal ICDs were tested for Electromagnetic Interference (EMI) in various orientations. Additionally, Sentinal ICDs were exposed to radiated electromagnetic fields at 450 MHz and 2450 MHz. The Sentinel ICD did not exhibit any changes from specification during the course of the testing. Testing for conducted radio frequency energy at the 100 mV level exhibited some interference.

- The System Programmer software applications consisting of the Model 2000 ICD, Model 2010/2011/2012 ICDs, and the DTS underwent a series of tests at the device and system levels. This testing verified that the software and the devices conformed to the requirements.
- The shelf life for the Sentinal ICD, leads and most accessories is 12 months. All packaging materials are commonly used industry materials that have been evaluated for their sealing integrity.
- A temperature storage test was performed on the Sentinal ICD where the device was exposed to +55°C and -30 °C for up to 96 hours. Final electrical testing after each temperature exposure demonstrated that the devices were unaffected by these temperature extremes. The recommended storage temperature for the Sentinal ICD is between -10°C and +55°C.

9.3 Lead System and Accessory Bench Tests

Testing of the AngeFlex Defibrillation Lead System included electrical and mechanical tests which included: flex fatigue, shock stability, thermal cycling, DC resistance, and connector tests. Additionally, the DTS, patient cables, and other system accessories were subject to various mechanical and electrical tests.

9.4 Biocompatibility Studies

The tissue/body fluid contacting materials of the Sentinel ICD System and the AngeFlex Defibrillation Lead System were evaluated for biocompatibility with the following tests: irritation, sensitization, cytotoxicity, hemolysis, pyrogenicity, mutagenicity, implantation and chronic toxicity tests. All of the implantable materials and processes are common to the industry and have a long history as implantable materials.

9.5 Animal Studies

Two animal studies were performed to evaluate the Sentinel ICD System and the AngeFlex Defibrillation Lead System. The first was a chronic study involving 21 canines that were followed over the course of two years. The study was performed to evaluate acute and chronic defibrillation thresholds, overall ICD/Lead performance, and to assess histiological affects. The ICD/Lead Systems performed in accordance with the established animal study protocol. The second study consisted of an acute evaluation of the performance of ICD Models 2000/2010/2011/2012, the System Programmer Models 3002/3007 (with Model 3008 Printer) in combination with various leads and accessories. This assessed overall system compatibility and evaluation of device performance to requirements. The ICD/Lead Systems and accessories performed in accordance with the established animal study protocol.

10.0 Clinical Study

The purpose of the clinical study was to evaluate the safety and effectiveness of the Sentinel ICD System Models 2000/2010/2011/2012 using the AngeFlex Transvenous Defibrillation Lead System Models 4020/4021/4022/4023, the AngePass Defibrillation Lead System 4040/4080 Series, the Endocure 1500 Series Defibrillation Lead System, or a chronic defibrillation lead

system under IDE #G950164. The study was initiated (first implant) on March 26, 1996. All centers used a common investigational protocol. The Sentinel ICD clinical summary includes data collected as of December 1, 1997, and includes information for 148 screened patients; 138 of whom were implanted with the Sentinel ICD. The AngeFlex Defibrillation Lead System was implanted in 70 patients, the Endocure lead(s) in 56 patients, the AngePass Lead System in 4 patients, and 8 patients had previously placed market approved chronic defibrillation lead systems.

Even though the Sentinel ICD performance data includes Sentinal ICD Systems implanted with the AngePass and the Endocure Defibrillation Lead Systems, Angeion is not seeking approval of the AngePass Defibrillation Lead System or Endocure Lead Systems with this PMA application.

10.1 Objectives

The key study objectives to determine the clinical safety and effectiveness included the following:

- Estimate the rate of successful conversion of VT/VF.
- Estimate the probability of 6 month survival from death by all causes over time.
- Estimate the probability of 6 month survival from cardiac death over time.
- Describe the performance of the AngeFlex Transvenous Defibrillation Lead System.

10.2 Patient Population and Gender Bias Analysis

10.2.1 Sentinel ICD System Study Patients

There were 148 patients screened and 138 patients who were implanted with the Sentinel ICD System at fourteen centers. As of the December 1, 1997 data cutoff, 103 patients were implanted for six months or more and 48 patients were implanted for twelve months or more.

Table 9: ***Description of Sentinel ICD System Patient Population***

Characteristics	Sentinel 2000	Sentinel 2010/2012	All
Mean Age at Implant Years (Range)	64.2 (36-82)	64.9 (38-86)	64.7 (36-86)
Gender:			
Male	34 (77%)	89 (86%)	123 (83%)
Female	10 (23%)	15 (14%)	25 (17%)
Mean Ejection Fraction % (Range)	32.2% (15-67%)	31.0% (15-70%)	31.4% (15-70%)

NYHA (New York Heart Association)			
I	20 (46%)	28 (32%)	48 (37%)
II	19 (43%)	41 (48%)	60 (46%)
III	5 (11%)	17 (20%)	22 (17%)
IV	0 (0%)	0 (0%)	0 N/A
Cardiovascular History*			
No History	1 (2%)	2 (2%)	3 (2%)
CAD	38 (86%)	75 (72%)	113 (76%)
MI	26 (59%)	67 (64%)	93 (63%)
CHF	16 (36%)	34 (33%)	50 (34%)
CM	16 (46%)	43 (41%)	59 (40%)
Primary Arrhythmia:			
VT	31 (70%)	63 (61%)	94 (64%)
VF	11 (25%)	25 (24%)	36 (24%)
VT/VF	2 (5%)	9 (8%)	11 (7%)
MADIT	0 (0%)	7 (7%)	7 (5%)
Implant Defibrillating Lead System Configuration			
RV/Can	9 (21%)	51 (53%)	60 (43%)
RV/SVC/Can	30 (72%)	39 (41%)	69 (50%)
RV/SVC	3 (7%)	6 (6%)	9 (7%)
Defibrillation Threshold (DFT) (# Patients)			
Implant - ICD	9.5J (6)	10.0J (12)	9.8J (18)
Pre-Discharge	8.5J (19)	10.2J (14)	9.2J (33)
1 Month	9.1J (21)	7.9J (6)	8.8J (27)
3 Months	10.8J (7)	9.0J (17)	9.5J (24)
6 Months	9.4J (17)	14.3J (1)	9.6J (18)

* Cardiac disease was indicated on case report form, however, *primary* cardiac disease was not, therefore these categories do not add up to 100%.

10.2.2 Gender Bias Analysis

Of all patients enrolled, 17% (N = 25/148) were females. Inclusion and exclusion criteria were chosen to avoid gender bias. The preponderance of male patients reflected the gender referral pattern for cardiac disease. Analyses of safety and effectiveness relative to male and female patients indicated no difference between the genders.

There were no statistically significant differences in the demographic variables between the Sentinel ICD Model 2000 and Model 2010 groups. These data are therefore considered poolable.

10.3 Study Design

The Sentinel ICD System clinical trial was conducted as a prospective, non-randomized, multicenter study. The study was designed to evaluate the Sentinel ICD System performance as compared to objective performance criteria. As this was the first device of its kind for Angeion, there was no Angeion predicate device to use for comparison or control. The objective performance criteria were established based on a review of the literature which described the performance of several market approved ICDs.

10.4 Clinical Results

10.4.1 Statistical Analysis

The safety and effectiveness of the Sentinel ICD System were demonstrated through various statistical analyses. The statistical methods used in analyzing the stratified data were: Pearson's χ to test for the significance of differences between variables that were categorical in nature; Kruskal-Wallis Analysis of Variance to determine the statistical significance of comparisons between groups where the dependent variable was ordinal in nature; Student's t-test for significance of differences between variables which were continuous; paired t-test to evaluate the significance of differences between measurements of continuous variables obtained on the same patients; and, Wilcoxon's Matched-Pairs signed-ranks test for measurements obtained on the same patient at different points in time or under different treatments. The Kaplan-Meier product limit survival method was conducted to analyze mortality endpoints at six months.

10.4.2 Induced and Spontaneous Arrhythmia Episode Experience

One of the primary endpoints was to demonstrate conversion efficacy, i.e., the Sentinel ICD System appropriately detects and terminates induced and spontaneous ventricular tachyarrhythmias. The data presented below includes induced and spontaneous VT and VF episodes from all implants and all follow-ups. Other rhythms are those that were deemed to be detected and attempted to be treated by the Sentinel ICD System but were not tachyarrhythmias (atrial fibrillation, sinus tachycardia, etc.). The induced data were witnessed by the investigator (or associate) and also recorded via the Sentinel Event History Log and via real time chart recorder. The Sentinel ICD memory (Event History) was used to verify spontaneous events.

Table 10: *Arrhythmia Conversion*

Sentinel ICD System Population (N = 148)

Arrhythmia Classification	Induced/ Spontaneous	Number of Episodes	Number of Arrhythmias Converted by Device
VT	Induced	472	471 (99%)
	Spontaneous	723	718 (99%)
VF	Induced	1215	1214 (99%)
	Spontaneous	61	61 (100%)
Other	Spontaneous	26	7 (27%)

10.4.3 Patient Survival

Survival from all causes and cardiac causes was also a primary study endpoint. A six month survival analysis was conducted after the first 100 enrolled patients reached the 6 month follow-up. These results were compared to the Objective Performance Criteria. Percentage of survival is based on Kaplan-Meier product limit analysis.

Table 11: *Safety Results*

SAFETY MEASURES	Total Survival		Objective Performance Criteria (OPC) (6 month survival)
	# alive patients/ # implanted patients	% survival (Kaplan-Meier)	
Survival: Cardiac Cause	130/136	97%	97%
Survival - All Causes	130/138	96%	93%

10.4.4 Clinical Events (Observations and Complications)

For purposes of the clinical study, the reported medical events were identified as observations and complications. An observation was defined as a physician reported symptomatic or asymptomatic clinical event with potential adverse effects which does not require invasive intervention. A complication is a similar clinical event but which requires invasive intervention. (Specific details regarding these events can be found in previous Tables 6 and 7).

10.4.5 Device Accountability, Reliability, and Longevity

Table 11 provides a summary of all Sentinel ICD Systems and associated leads used in the Sentinel ICD System clinical investigation.

Table 12: *Device Accountability*

Total devices implanted: Sentinel ICD System (N = 143*), AngeFlex Defibrillation Lead Systems (N = 70), Endocure lead system (N = 56), and other lead system (N = 12).

	Sentinel 2000	Sentinel 2010/2012	All
Devices Implanted:	42	101	143*
Still Active	38	92	130
Out-of-Service	4	9	13
Out-of-Service Devices:	4	9	13
Due to Deaths	2	6	8
Due to Explant	2	3	5
Not Returned	2	5	7
Analyzed	2	4	6
Returned Devices	2	4	6

* Includes 5 replacement devices

11.0 Conclusions Drawn from the Studies

Prior to the start of U.S. clinical studies, the Sentinel ICD System and AngeFlex Defibrillation Lead System were subjected to comprehensive bench testing at the component, subassembly, device and system levels. All materials contacting tissue and body fluids were evaluated for biocompatibility. Acute and chronic animal studies were also conducted with all of devices included in the PMA application. In addition, the safety and effectiveness of the Sentinel ICD

Systems were also comprehensively evaluated and demonstrated through the clinical studies. Therefore, it is reasonable to conclude that the benefits of use of the device for the target population outweigh the risk of illness or injury when used as indicated in accordance with the directions for use.

12.0 Panel Recommendation

In accordance with the provisions of section 515(c)(2) of the act as amended by the Safe Medical Devices Act of 1990, this PMA was not referred to the Circulatory System Devices Panel, an FDA advisory committee, for review and recommendation because the information in the PMA substantially duplicates information previously reviewed by this panel.

13.0 FDA Decision

Based on the review of the original submission and its amendments, the applicant has addressed all the major issues. FDA issued an approval order on August 19, 1998. The applicant's manufacturing facility was inspected on April 8, 1998, and was found to be in compliance with the device Good Manufacturing Practice regulations.

14.0 Approval Specifications

Directions for use: See the labeling.

Hazards to Health from Use of the Device: See Indications, Contraindications, Warnings, Precautions and Adverse Events in the labeling.

Post-approval Requirements and Restrictions: See approval order.

The Approval Order, Summary of Safety and Effectiveness Data, and labeling can be found on the Internet at http: //www.fda.gov/cdrh/pmapage.html.